Vol. IX. SEPTEMBER, 1892. No. 5.

THE AMERICAN METEOROLOGICAL JOURNAL.

A MONTHLY REVIEW OF METEOROLOGY.

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THE AMERICAN

METEOROLOGICAL JOURNAL.

VOL. IX. BOSTON, MASS., SEPTEMBER, 1892. No. 5.

PAPERS FROM THE LABORATORY OF PHYSICAL GEOGRAPHY OF HARVARD COLLEGE.

No. 7. — OBJECTIONS TO FAYE'S THEORY OF CYCLONES (*Continued*).

WM. C. MOORE.

Surface Indraft.—From what precedes, I think it must be admitted that there is strong evidence in favor of an upper outflow from the centre of the storm, the apparent direction of the outflow being more or less modified by the progression of the storm. In this we are also supported by the observed motions of the surface air. If these storms were descending whirls, the air brought down, in escaping from the bottom, must give an outward departure from a circular path to the surface winds; hence if storms are descending whirls there can be no surface indraft; but that a surface indraft is a characteristic of storms has been proved by many observations. Espy, in 1840, was the first to call attention to the fact that the surface winds flow inward. His conclusion was then known as the radial theory, and excited much attention, for it was in direct opposition to the then generally accepted circular theory of Redfield. Espy "had found, by examining simultaneous observations in the middle of storms and all round their borders, that the wind blows inward on all sides of a storm towards the central parts; towards a point if the storm is round, and towards a line if the storm is oblong, extending through its longest diameter. Next he had been able to investigate within the last five years seventeen storms, without discovering one exception to the general rule." *

* Espy, Philosophy of Storms, 1841, V., Introduction.

"From all these facts he demonstrated that there is an inward motion of the air towards the centre of the storm from all sides, and maintained that this is the inference which ought to be drawn from the well-known fact that the barometer stands lower in the midst of a storm than it does all around its borders."*

In later years Espy did not adhere strictly to radial inflow: "When several logs were read and arrows made in every locality (on the map), I was not a little pleased to see, in all the storms, decided proofs of an inward motion of the air, if not exactly to a common centre, quite as nearly so as any one had a right to expect, because oblique forces are known to exist which vary the direction of the wind." †

Redfield, upon whose laws Faye bases his theory of storms, also begins to recognize the spiral indraft, and in 1846 writes the following often-quoted passage: "When in 1830 I first attempted to establish, by direct evidence, the rotative character of gales or tempests, I had only to encounter the then prevailing idea of a general rectilinear movement in these winds. Hence I have deemed it sufficient to describe the rotation in general terms, not doubting that on different sides of a rotary storm might be found any course of wind from the rotative to the rectilinear. But I have never been able to conceive that the wind in violent storms moves only in circles. On the contrary, a vortical movement approaching to that which may be seen in all lesser vortices, aerial or aqueous, appears to be an essential element of their violent and long-continued action, of their increased energy toward the centre or axis, and of the accompanying rain. In conformity with this view, the storm figure on my chart of the storm of 1830 was directed to be engraved in spiral or involute lines, but this point was yielded for the convenience of the engraver." ‡ Compare this with what Faye says in speaking of Redfield's views on this subject: "Redfield, intimidated, perhaps, by the assurance of his antagonist (Espy), ended by conceding that in cyclones there might be some traces of centripetal motion." §

Willson, in his "Report on the Midnapore and Burdwan

* Ibid VII. † Philosophy of Storms, 190.

‡ Redfield, Hurricanes and Northers, 1846, 16.

§ Am. Met. Jour., VI., 1889–90, 499.

Cyclone," writes as follows upon this subject: "According to the earlier writers, cyclones were believed to be true circular storms, but it has gradually been brought to light by carefully plotting on charts synchronous wind observations made in different storms, that the air currents do not blow round the centre in concentric circles, but in spiral curves, which at a distance from the centre are nearly rectilinear, but whose curvature increases on approaching the vortex." "For the last ten or twelve years the circular theory has been gradually abandoned by those meteorologists who have made the subject a special study."*

Viñes cites specific illustrations in which surface indraft has been observed. In the hurricane of September, 1875, he reports that in the front part of the storm the winds were circular, coming from the north-northeast and north, but in the rear there was a notable convergence. As the storm went on to the west-northwest the wind changed from the south to the south-southeast, then to the southeast, and finally to east-southeast, instead of from the south to south-southwest, as the circular theory would require. This was true for a number of places of observation; and some of them were not far from the centre. In the hurricane of September, 1876, practically the same thing is found; in front either sensibly circular or slightly inclined, and in the rear a strong convergence, especially as the centre departed. In the hurricane of October, 1876, there was without doubt the most distinct and most general convergence. In this case the winds in front showed an inclination, but less distinct than the strong inclination in the rear.

Ley has determined the average angle of inclination in European cyclones from many observations made in the British Islands and the adjacent parts of the continent. His principal results were: 1st. The winds commonly incline considerably from the districts of higher towards those of lower pressure. The collective mean for fifteen stations is 20° 51′. 2d. This inclination is much greater at inland than at well-exposed coast stations. The collective mean for Brest, Sicily, Yarmouth, Pembroke, and Holyhead is 12° 49′, while that for five inland stations — London, Nottingham, Oxford, Brussels, and Paris — is 28° 53′. †

* W. G. Willson, Report on Midnapore and Burdwan Cyclone, Calcutta, 1875, 85.

† Jour. Scottish Met. Soc., VIII., 1873, 66.

The winds, however, do not always incline towards the centre of low pressure in all latitudes. Knipping finds instances in which there is an outward departure from a circular path of the surface winds in the front part of a storm in the higher latitudes. This peculiarity may be accounted for by considering the effect of combining a large onward motion with the cyclonic motion.

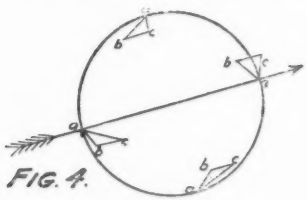


FIG. 4.

"Let a b (Fig. 4) represent the velocity and direction of the cyclonic motion on the several sides of the cyclone with its centre progressing a little north of east, as usual in the middle latitudes, and as represented by the arrow, and also let b c represent the velocity and direction of the wind at the earth's surface, which may be assumed to be the same, or nearly the same, in all parts of the cyclone, and to have very nearly the same direction as that of the cyclone centre, but its velocity is generally much less. It is seen from the figure that the resultants represented by a c indicate very different velocities and inclinations onthe different sides of the cyclone." . . .

"On the front side only is the direction very much changed, since nearly the whole effect of the progressive motion of the air is upon the direction of motion and not upon the velocity. The inclination here, with the assumed relation between progressive and cyclonic velocity, is negative, or outward." "Of course the relations between the resultant velocities and directions and those of the cyclonic depend upon those between the two components. If the progressive velocity of the air is small in comparison with the cyclonic, as is usually the case on land, the cyclonic velocities and directions are not much changed; but this is generally different at sea, where the progressive velocity of the air is usually greater. The relations (represented in Fig. 4) are perhaps those which usually occur at sea, where the progressive velocity may be nearly as great as the cyclonic." *

It is found that as the inflowing winds approach nearer and nearer the centre they increase in curvature, and at a short distance from the centre are sensibly circular. Faye may say

* Ferrel, Popular Treatise on the Winds, 1889, 303.

that these circular winds which we find to exist at the centre of the storm are the true whirls, and that these incurving drafts are only the result of the diminished atmospheric pressure caused by the upper overhanging spirals of the whirl, but these indrafts which he says may occur in the region exterior to the cyclonic whirl he characterizes as only stray breezes of feeble tendency towards the cyclone,* while the indrafts which have been observed are continuous and persistent, and have the violence of hurricanes.

The earliest recognition of the whirling character of storms was by Col. Capper, in 1801. He states his belief that hurricanes will be found to be great whirlwinds, and that the place of a ship in these whirlwinds may be ascertained, for the nearer the vortex the faster will the wind veer. Redfield was the first to give any just notion of the nature of hurricanes. Then followed the modifications consequent upon the discoveries of Espy and various others. The same result is reached whether we approach it from the observational side of Espy, Willson, Viñes, and others, or from the theoretical side of Ferrel. To return now to the circular theory is to ignore the advance which has truly been made.

Clouds and Rain. — According to Faye, the abundant precipitation which nearly always accompanies cyclones is accounted for by the cooling of the air by the ice crystals of the cirrus clouds which are brought down by the whirl. It is seen by referring to the following diagram † that the air in

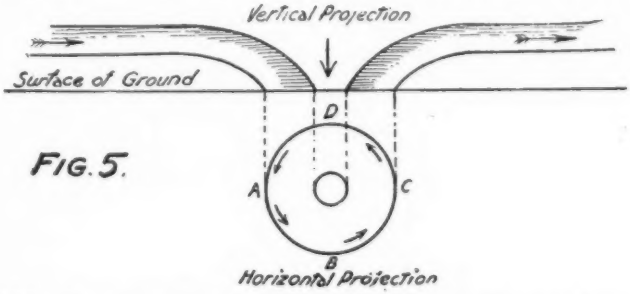


FIG. 5.

which the condensation takes place is brought down from a higher level, the level of the cirrus current. Circle A B C D

* Am. Met. Jour. VII., 412. † Reproduced from Am. Met. Jour. VI., 411.

represents the true limit of the cyclone; it is formed where the descending whirl meets the ground. At the height of these cirrus clouds the temperature of the air is very low (Faye places it at —30 C.), hence the air cannot contain much water vapor; these rapidly moving whirls will not mix with the surrounding air to any extent, so that the amount of moisture present will not be increased from this source. As this air is brought down its temperature increases, and likewise its ability to hold moisture increases. What, then, is the source of all this precipitation? Surely the melting of the ice crystals as they are brought down is not sufficient to cause torrents of rain. When we take into consideration the great amount of rainfall which is reported, it seems as if the supply of cirrus is inadequate to do what the theory requires of it. In tropical cyclones the rainfall is characterized by such terms as excessively heavy rain, incessant heavy rain, deluge of rain, etc. In the cases where a rain-gauge was used the measurements have shown that the preceding terms were no exaggeration. Faye says: "It (the cirrus) determines in its passage the condensation of the moisture of the lower strata." * If this be true, the greatest precipitation ought to take place around the borders of this circle marked "A B C D." Observations show that in tropical cyclones the rainfall is very great near the centre, amounting to one and one half to two inches per hour. During the passage of a storm a rainfall of from ten to twenty inches is of comparatively frequent occurrence, and of from twenty to thirty inches of occasional occurrence. When we remember that for the cirrus to produce this precipitation it must overcome the heat of compression in the air brought down from above, which amounts to 1.6° F. for every three hundred feet of descent, and also the latent heat liberated by whatever condensation of vapor takes place, it is evident that the theory fails to give sufficient and satisfactory treatment to this very important subject. Now reverse these conditions, and make the current an ascending one. How much more reasonable it is to believe that the precipitation is caused by the adiabatic cooling of the air in its ascent; and in considering the current an ascending one we are supported by the facts of inflow at the bottom, whereas if it

* Am. Met. Jour. VI., 362.

were a descending current it would require an active outflow beneath. We do not deny that the ascending current may not at times be crowded and forced down by the upper currents but, as Hann says, we regard these happenings as antics.

Trajectory of Storms.—In accounting for the path taken by storms, Faye says: "Should a whirl form in the current, it will describe precisely the trajectory of a storm, in following the direction of the current," * and again: "Consequently the trajectory of each cyclone is the projection upon the surface of the generating current."† Now these whirls are formed according to his theory at the point where the aerial stream is turned back from the westerly course, which it has been pursuing, to the northeasterly course, which it takes in its journey towards the poles, and it is by considering that the whirls are formed at this point that he accounts for the gyrations from right to left (page 360). The latitude at which this northeasterly movement takes place is found to be between 10° and 15°,‡ and yet between these latitudes a hurricane moves almost due west, and does not begin to recurve in June and October until it reaches about the twentieth or twenty-third parallel, in July and September at about latitude 27° or 29° N., and in August, 30° or 32° N.§ Hence, if these whirls are formed at the place where the upper current takes on the northeast course, as quoted below, then the path of the storm while it moves westerly and northwesterly does not coincide with the upper current, as the theory demands.

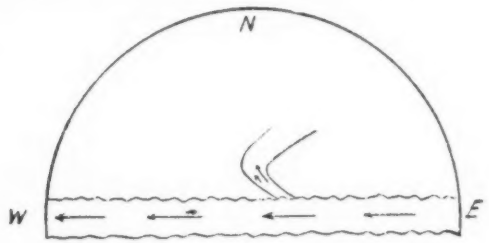


FIG 6

Gyrations.— Faye accounts for the gyrations from right to left as follows: "Since the aerial stream makes a marked bend

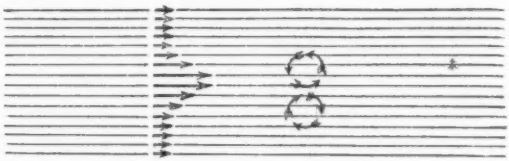
* Vol. VI., 360. † Ibid., 503.

‡ Am. Met. Jour., I., 1884, 1885, 50.

§ Everett Hayden, W. I. Hurricanes and the March Blizzard, 1885.

towards the east, it is the threads on the left which have the least velocity; consequently, if a whirl is formed there, the gyrations will be from right to left in our hemisphere, and from left to right in the opposite hemisphere." * The question presents itself, Why should not whirls be found at other places in this stream where the conditions may be such as to cause whirls in the opposite direction? For example, the whole mass of air in which the current flows is moving, and the movement of the threads in the right-hand part of the current will be faster in relation to the movement of the air on the borders of the current. We have the conditions as represented in Fig. 7. Let

FIG. 7.



the arrows represent the velocity and direction of the threads of the stream and of the air on the borders of the current. If we apply the same reasoning which Faye uses † what will prevent the formation of right-handed whirls from these inequalities of motion in the same way in which the left-handed whirls are formed?

Gradual Formation of Cyclones.— Faye makes the following statement in support of his belief that storms originate in the upper strata of the atmosphere: "If storms, cyclones, etc., originated below and developed little by little, in a given place, for example, as the result of persistent insolation, and then put themselves in motion with the speed of a locomotive, it certainly would happen that among the millions of spectators at least a few would be found who had witnessed their formation and would have seen them develop, more or less rapidly, near the ground. This has never happened." ‡ Faye's prediction in this instance is a true one, but when he says it has never happened, I think he probably does not know what has been learned from the observations of the cyclones of the Bay of Bengal, viz.:

"It should be kept carefully in view by mariners in the Bay of Bengal that the formation of a cyclonic storm is a gradual

* Vol. VI., 360. † Vol. VI., 355. ‡ Vol. VI., 414.

process, and that it is only when the disturbance has passed beyond the initial stages that it becomes a storm in the proper sense of the word. The formation of a large storm is due to the prolonged continuance of actions, processes, and changes of the same kind as those that are occurring in the atmosphere at all times when rain is falling and strongish, humid winds are blowing. Whatever the causes and origin of cyclones may be, the history of all cyclones in the Bay shows that they are invariably preceded for longer or shorter periods by unsettled, squally weather, and that during this period the air over a considerable portion of the Bay is gradually given a rapid rotatory motion about a definite centre. During the preliminary period of change from slightly unsettled and threatening weather to the formation of a storm more or less dangerous to shipping, one of the most important and striking points is the increase in the number and strength of the squalls, which are an invariable feature in cyclonic storms from the very earliest stages. First of all, the squalls are comparatively light, and are separated by longish intervals of fine weather, and light, variable, or steady winds according to the time of year. They become more frequent and come down more fiercely and strongly with the gradual development of the storm. The area of unsettled and squally weather also extends in all directions, and usually most slowly to the north and west. If the unsettled weather advances beyond this stage (which it does not necessarily do), it is shown most clearly by the wind directions over the area of squalls. The winds always settle down into those which invariably occur over an area of barometric depression or cyclonic circulation, or, in other words, are changed into the cyclonic winds of indraught to a central area of low barometer and heavy rains. As soon as the wind directions indicate that a definite centre of wind convergence has been formed in the Bay, it is also found that the centre never remains in the same position for any considerable interval of time, but that it moves or advances in some direction between northeast and west with velocities which not only differ very considerably in different storms, but also at different stages of the same storm. This preliminary period of unsettled, squally weather may extend over several days, or may last only a few hours. It is of course impossible to define the particular hour at which the change from the antecedent disturbed squally weather to the cyclonic storm takes place." *

Conclusion. — Evidently there is either an ignorance of the facts on M. Faye's part, or a total disregard of what others have done. He accuses other meteorologists of insincerity, — of

* Eliot, Handbook of Cyclonic Storms in the Bay of Bengal, Calcutta, 1890, 89.

attempting to make facts conform to a previously conceived theory, — but it is not likely that the great body of observers are all bent upon supporting a theory which matters nothing to them if it be proved unsound, nor is it likely that they have all made the same mistakes in their observations. We have attempted in this article to refer to facts which have been observed by reputable observers, and to make these facts, and not opinions, our authorities. M. Faye has apparently not considered all the conditions his theory demands or he would have recognized the necessity of such things as the convergence of inflowing cirrus at the top, and the active outflow of air at the bottom, as well as the improbability of producing rain in a descending mass of air. He contradicts his master, Redfield, on a point which Redfield considers an essential element of cyclones. In this article we have considered only a few of the more essential characteristics of cyclonic storms; nevertheless it must be evident that the generally accepted theory of convectional or apparently convectional motion gives a more rational and satisfactory explanation of the various phenomena than the theory which we have been examining.

HARVARD COLLEGE, June, 1892.

CHANGES OF PLANE OF THE MISSISSIPPI RIVER.

PROF. THOMAS RUSSELL.

THE report of the chief of engineers for 1891 contains a very valuable and interesting paper on high-water stages of the Mississippi River by Lieut. Col. Chas. R. Suter of the Mississippi River Commission. A phenomenon of the river is traced out by a discussion of the gauge records and discharge measurements at a number of places to which the name, changes of plane, is given.

The paper is in the main on points relating to the improvement of the river and methods of preventing overflow. Below is given a summary of the paper of interest for the bearing it has on the accuracy with which high-river stages can be predicted.

The stage of water in a river and the discharge or quantity of water passing at the time are closely related. The higher the stage, that is, the greater the gauge reading, the greater the discharge. The stage is the vertical height of the river surface in feet above the plane of low water. The discharge is the number of cubic feet of water passing through a cross-section of the river in a second.

It is customary to represent graphically the relation of discharge to gauge, for different stages, by a diagram on a sheet of paper. A series of points plotted with the ordinates to represent gauge readings and the abscissas discharges when joined by a line is known as a discharge curve. The curve for a place is always nearly the same. There is some difference for a rising and falling stage of the river. But on the whole a discharge curve is tolerably constant, the corresponding discharges for the same stage at different times being nearly equal.

The discharge curves for two places on a river may differ greatly. With a gauge range of twenty-five or thirty feet from low to high water at one place, for the same discharge at another the range may be fifty feet. Since there is a definite relation between gauge and discharge at a place, it follows that for two places on a river with the same discharge the gauges must have a definite relation.

The relation between two gauges is shown graphically on a sheet of paper by a line joining the points of intersection of ordinates representing one gauge and abscissas the other. In the case of two gauges with no tributary coming into the river between them, this is a straight line more or less inclined in the ratio of the relative oscillations from low to high water at the two places. When a tributary intervenes it is not a straight line but a curve.

In determining the line that shows gauge relation in the case where a tributary comes into the river between the places, allowance is made to the gauge reading for the volume of water added by the tributary. This is necessary to render the lines comparable, as the volume coming from the tributary may be very different at different times, and, if not allowed for, the relation of a gauge reading above and below the tributary need not be the same.

The time interval is also taken into account, depending on

the distance between the gauges. From a study of the hydrographs (curves showing stages as ordinates and days of the year as abscissas) and from a comparison of all the series of simultaneous discharge measurements which have been made, it appears that for all portions of the stream as far down as Red River the rate of travel of discharge is about seventy-five miles in twenty-four hours at all stages except dead low water and general overflow.

Singularly enough, this rate is nearly constant, regardless of the fact that the velocity of the water throughout a cross-section is very different at different stages of the river. Between Red River and Carrollton (near New Orleans) this rate of transmission of discharge is one hundred and ninety-two miles in twenty-four hours, — some two and one half times as great as for points above.

Discharge curves and lines or curves showing gauge relations are as a rule only constant in their inclination. Their absolute positions on a sheet of paper vary from year to year, being higher or lower. Something happens to produce a change and there is a shift of the curve up or down. The gauge relation and the discharge curve show the same thing independently. It is such a phenomenon as might be expected if the whole river, at such times, was raised or lowered, changing its plane of flow while the gauge remained unchanged. Hence they are called changes of plane. These changes may amount to a foot or several feet; that is to say, the zero of the discharge curve is raised or lowered that amount.

The discharge measurements on the Mississippi for 1884 and 1885 show that from at least Helena, Ark., these changes are transmitted downstream. They are cumulative. A change at Helena may be added to another at the mouth of White River, the Yazoo, and the Red, the final change at Carrollton being the sum of the whole. Their effect may last nearly a year or from one low water to another. The changes of plane occur mainly at the mouths of tributaries. At Red River, December and January, 1884 and 1885, a very abrupt change occurred, being an elevation of 5.8 feet. It was maintained throughout the season. On it was superposed a change of 3.35 feet transmitted from Helena. The gauge relation with Vicksburg shows it was not eliminated until the low water of 1885 had set in.

The changes of plane, it is surmised, are due to local engorgements of the river. The discharge of a tributary not being in harmony with the main stream and diminishing its relative mean velocity, changes the ratio of discharge to gauge. The water of Red River seems to partly fill the channel, as so much sand or mud, and to remain there, so the water coming from above has to climb on top of it in order to continue its way to the sea.

In 1886, 1887, the Red River was low for an unusually long period. When it rose it reached a height of thirty-two feet at Red River Landing, with a deviation from the primary plane of the year of less than two feet. Then came a rise in the Red River followed by a decided change of plane in the Mississippi at Red River Landing. In the succeeding year, December, there was an inflow from Red River at a time when the Mississippi there was at a very low stage, six feet, on the Red River Landing gauge. It was accompanied by a change of plane which persisted throughout the season.

That these changes are local engorgements is shown by the effect at Natchez, sixty-five miles above Red River. The gauge relations with Vicksburg show that for all except low stages changes of plane occur at Natchez of the same character as at Red River Landing, but less in amount. They occur at Natchez on an average two days later, showing that they are back-water effects.

The tables given in Col. Suter's paper show in a general way, as he states, that for Red River Landing and Carrollton, in every year for which there are observations, there is an abnormal elevation of the plane of flow at extreme stages at both places. At Red River it has amounted to as much as thirteen feet and at Carrollton to 5.4 feet. The tables also show that if the levee system had been perfect from Vicksburg to Carrollton the actual mean maximum gauge readings at Red River Landing would have been increased 0.43 of a foot and at Carrollton 1.11 feet, while under the same conditions, but with the Red River shut out, the actual mean maximum at Red River Landing would have been reduced 7.29 feet and at Carrollton 2.09 feet. These are large figures, and their importance, as regards the levee problem, can hardly be too highly estimated. To be able to bring down the flood-levels below

Vicksburg to such an extent, especially in view of the fact that larger discharges than any hitherto known must in the near future be provided for in that section of the river, would go a long way towards insuring the permanent redemption of Louisiana from overflow.

If the facts are sufficient to show that Red River instead of being at best a doubtful friend is in reality a most treacherous enemy, it is the imperative duty of the Commission to reconsider their plans for this portion of the river, to divorce the Red River permanently from the Mississippi, and to provide, at some point, a canal between the two streams.

The above is substantially Col. Suter's paper and his line of comment.

There are great inherent difficulties in any treatment of river data.

On examining the diagrams in Col. Suter's paper it occurs to the writer of these remarks that the changes of plane are in most cases small. The changes are complicated with the additions of water coming into the river from the tributaries, and it does not appear how accurately this additional water can be allowed for in causing a change of gauge reading. Unless the change and the addition can be disentangled no fair idea can be formed of the magnitude of the change. The changes are mostly of such an order as might be expected from imperfection of the data.

The most carefully made discharge measurements may be in error five per cent of the whole amount. The variation of stage corresponding to this for a high stage, where the river has an average depth of fifty feet, would be about 2.5 feet. It would seem from this as if discharge measurements could not be relied upon to establish changes of plane except when very considerable.

Gauge readings can be made accurately to the tenth of a foot. The results from gauge-relation curves are more trustworthy in tracing changes of plane than discharge curves.

The gauge relation for two places on a river is not necessarily always the same. The gauge readings that will be attained at a lower station will depend materially on the rate of rise at an upper station. With a rapid rise and fall at an upper station the gauge readings at points below will not be as great as with

a slow and prolonged rise at the upper points. This objection does not hold, however, for the case of the lower Mississippi River, where the rises are slow and the wave crests, as shown by the hydrographs, are always of about the same shape.

WEATHER BUREAU, WASHINGTON, July 25, 1892.

THUNDERSTORMS IN NEW ENGLAND DURING THE YEAR 1887.

R. DE C. WARD.

IN the May number of this JOURNAL the writer gave a brief summary of the results derived from a study of the thunderstorms in New England during the year 1886, the materials for that study consisting of the records made by volunteer observers for the New England Meteorological Society. The present report deals in a similar brief manner with the results obtained with reference to the thunderstorms of 1887, a fuller account of which will shortly be printed in the Annals of the Astronomical Observatory of Harvard College.

The following table gives the number of days in each month on which thunderstorms were reported, and the number of days on which the storms showed distinct movement:—

Month.	Days on which Thunderstorms were Reported.	Days on which Storms showed Movement.
January	1	0
February	1	1
March	0	0
April	5	0
May	6	0
June	18	7
July	29	16
August	20	13
September	6	2
October	4	2
November	1	0
December	1	0
Totals	92	41

June, July, and August were, as is seen from this table, the months of most frequent reports, and July had the greatest num-

ber of distinct storms, averaging one storm every two days. The only thunder heard in February was in connection with a well-defined storm, showing distinct progression, apparently an unusual occurrence in that month. The days on which the storms had progression were forty-four per cent of the whole number of days on which thunder was reported. The hours of maximum frequency of thunderstorms during the year were 3.30 to 5.30 P. M. About twenty per cent of all the storms noted occurred in the morning, their hours of greatest frequency being 4.30 to 8.30 A. M. The average rate of movement of all the storms during the year was between thirty and thirty-five miles an hour. The highest velocity noted was fifty miles, the lowest, fifteen miles.

During June, eleven storms with distinct movement were noted, on seven days. In four cases, the Washington 7 A. M. maps showed a cyclonic area over the Lakes. Of the remaining days two had low-pressure areas off the Gulf of St. Lawrence, and one had nearly normal pressure, with no defined centre of low pressure. The small number of thunderstorms in this month was undoubtedly due to the prevailing anticyclonic conditions, which were a distinguishing feature of the month. On fifteen of the remaining twenty-three days the pressure over New England was above the normal, and on four, very slightly below the normal. On the four remaining days the conditions seem to have been favorable for the development of thunderstorms, but no distinct ones occurred, although on three of these days there were scattering reports of thunder.

In July, twenty-four storms possessing distinct progression were noted, on sixteen days. In five cases, the centre of low pressure was over the Lakes ; in four, over the Gulf of St. Lawrence ; four had pressure above the normal ; one had the low-pressure area central over New England, one over the lower St. Lawrence, and in the last case there was no definite centre. Of the remaining fifteen days of the month, on which no distinct thunderstorms occurred, eight had anticyclonic conditions with pressure above the normal, as shown on the 7 A. M. maps ; one had pressure but slightly below the normal ; three had cyclonic centres over the Lakes (but two of these had nearly normal pressure) ; two had cyclones central over the Gulf of St. Lawrence, and one had a cyclone central off the coast. It

appears again from this investigation that when the pressure is above the normal thunderstorms are unlikely, but why no storms occurred when there were cyclones central over the Gulf and the Lakes is not apparent, the conditions on these days not differing, as far as has been seen, from those on days when thunderstorms did occur. The anticyclonic days which brought thunderstorms had the high pressure centre off the coast to the south of New England; on those which did not produce storms the anticyclone was central to the northwest or northeast.

In August, eighteen storms with marked progression occurred, on thirteen days. On three of these the pressure was above the normal with anticyclonic conditions of weather; two had pressure slightly below the normal, with no clearly defined centre; three had cyclonic areas over the Lakes; two had them over the Gulf of St. Lawrence; in one case, the low-pressure centre was over the St. Lawrence; in another, off the southern coast, and in the last case the pressure was low with no defined centre. An examination of the maps on days when no thunderstorms occurred showed the following conditions: Of the eighteen days left, nine had pressure above normal, and generally clear or fair weather; four had pressure slightly below the normal (with an anticyclone approaching over the Lakes in three cases); two had cyclones central over the Gulf of St. Lawrence (one with an anticyclone approaching over the Lakes); two had ill-defined low-pressure areas over New England (one with an anticyclone over the Lakes); and one had a cyclonic area south of Nova Scotia, also with an anticyclone over the Lakes.

During September three storms were noted with definite progression, on two days. On one day the 7 A. M. map showed a cyclonic area central north of the Lakes, with strong gradients over New England; on the other the pressure was above the normal, with a moderate cyclonic depression central over Illinois.

The most interesting storm of the summer was that of July 29, which occurred with nearly normal pressure over New England, and which exhibited several noteworthy features. After it had moved over to the east, in the usual fashion, it returned again, as noted at six stations in Massachusetts, moving towards

the west for a time, and then continuing its interrupted course eastward. It is a matter of regret that there are not enough records of this unusual feature to allow a definite statement to be made. The changes of wind, as noted by many observers, were very marked, and seem to indicate a cyclonic indraught toward the storm, a feature already noted in connection with thunderstorms in Europe and in this country.

The "dividing" of the storm is one of the most frequent notes made in the reports, and but little further light has been gained on this interesting point. Many observers state it as a recognized fact that thunderstorms always divide before reaching their particular town. The only further point that has been gained in this connection is in the case of the storm of July 6, which, starting in western Vermont, Massachusetts and Connecticut, and moving eastward, did not traverse Massachusetts, though it was noted in New Hampshire and Maine on the north, and in Connecticut on the south. A great break of fifty miles was thus left in the middle of the storm. In the storm of July 25 two stations in an east-west line note a "dividing," which shows the progression of the break eastward with the storm, as was seen in the case of the storm of July 18, 1886. With regard to direction of movement, the most remarkable storm noted was that of July 18, which apparently moved from north to south. On July 30 and Aug. 30 some observers speak of the storms as stationary, and in that of July 30 a wind was noted blowing out of the rear of the storm.

In comparing briefly the results of the investigations of 1886 and 1887, it will be seen that they accord in most particulars. A notable difference is however seen in the relation of the cyclonic centres and the positions of the thunderstorms. While in 1886 the majority of thunderstorms (over sixty per cent) occurred in the southern or southwestern quadrant of cyclones central north of New England, in 1887 the majority of the storms occurred in the southeastern quadrant, or under anticyclonic conditions. Only forty per cent of the summer thunderstorms of 1887 occurred in the southern part of cyclonic storms, while in 1886 the number is seventy per cent. It is evident from this study that the prediction of thunderstorms for New England is a difficult task, and that no very definite rules can yet be laid down. A few general conclusions with regard to the probable

occurrence or non-occurrence of local storms based on the weather and pressure conditions of the morning weather map are the only results of this investigation, so far as forecasting is concerned.

HARVARD COLLEGE, July 28, 1892.

WEATHER FORECASTING AT THE SIGNAL OFFICE, JUNE 30, 1891.*

PROF. H. A. HAZEN.

ON July 1, 1891, the duties of the Signal Office were divided, a part going to the Signal Corps proper, and another part, that relating to the weather, was transferred to the Weather Bureau. It has seemed advisable to note a few of the more salient points and principles that have been established by the Signal Office in its work of forecasting the weather. It has been suggested that this work is done by intuition, and that it would be almost impossible for a good forecaster to impart his knowledge to another. This views needs a little explanation, I think. It means that long years of practice are needed to enable one, at a moment's glance, to grasp the more important points on a weather map, and to determine just what the indications are for the near furture. It means that we can not draw up a formula into which we can enter certain quantities and then solve the equation. While a forecaster learns, by practice, to read a map quickly, yet I think, if called upon at any time to give a reason for a certain forecast, he would be able to explain his train of thought, though at the moment it may have come to him without a long study.

My own experience in this work has been since September, 1887, only. I found that no general principles had been laid down, and that it was necessary for each one to work out his own principles by a study of the maps. It must be admitted that there was a certain advantage to be gained in this experience, for by it one does not get his information second-hand, or in a way which he would find it difficult to apply, but he learns

*From the Annual Report of the Chief Signal Officer for 1891. Appendix 3.

the work little by little, and by repeated failures finds just what he is able to tell fairly well and just where the doubtful points are. To my mind, however, there are certain fundamental ideas which can be written out quite easily, and which will be of great help to a beginner in this work.

Average Conditions only to be Predicted. — First: We can hope to predict average conditions only; that is to say, taking five hundred maps in any month, the person who could go through those maps and make the best predictions, taking them as a whole, would be the most successful forecaster. Another person might do better on a hundred of the maps, but he could not take up a new map for that month and do as well as the first. The importance of this point may not at first be recognized. It is very essential to fix distinctly in mind that one must expect to forecast on an average condition only. If he finds a particular case in which he has failed he must learn to feel that, were a similar case to come up, or even the very same case, he would make exactly the same prediction. It seems to me the best goal to set before one in forecasting is to be able to make the same prediction from the same map, over and over again, no matter how many months have intervened between the trials, and though each attempt should give not more than seventy per cent as a result, for I feel sure there are such maps. If a person finds he has failed in any particular case, and tries to apply that semingly new principle on a subsequent apparently similar map, he will again fail, because the original forecast depended on an average condition and the second map was an average map.

A good example of this principle has been recently called to my attention by Prof. Carpmael, of Toronto, Canada. Several years ago one of his forecasters predicted a thaw on a map that had every appearance, as Prof. Carpmael thought, of a hard freeze; but sure enough the thaw came. Two or three years afterward another forecaster, in examining the old maps, came across the above abnormal case, and it so happened just about that time he had a map exactly like the former, and because of the success in the former case he predicted a thaw. When Prof. Carpmael saw the map he decided at once that there would be a very severe cold wave, and calling the attention of the forecaster to what the map seemed to indicate, he was shown the previous map on which the prediction of a thaw had been suc-

cessful. In the second case, however, there was a very hard freeze, one of the worst of the whole winter. This would also seem to show that we cannot predict very satisfactorily upon the idea of types, but every map must be studied on its merits alone, without trying to find a previous one that looks almost exactly like it.

Persistency of Weather Conditions. — Another principle to be borne in mind is that prevailing conditions are, as a general thing, more likely to continue than to change. We have common proverbs which enforce this principle: "All signs of rain fail in a dry time," "It will not stop raining till the moon changes," etc. It will be repeatedly found that when clouds are breaking away after a long rain it is unwise to forecast clearing for at least twelve hours. This is specially true for the Lake regions and the mountains of the east part of the country. One of the first rules that a forecaster learns is that he is likely to anticipate altogether too much rain, and that there is often a remarkable persistency in fair weather conditions. Even after clouds come up in the southeast quadrant of a storm, unless rain has already begun falling to the westward, it is very dangerous to predict rain. This is especially the case if the high area in front of the storm has any tendency to the south or southeast.

Forecasts cannot be made on General Laws. — The ordinary theory is that rain is generally caused by the condensation of moisture in an ascending current of warm, moist air. It is certain, however, that no use whatever can be made of this theory in forecasts. Rain certainly does not occur at the centres of our storms, where we would naturally expect the strongest upward tendency. It does fall frequently in the southeast quadrant of storms; but even this rule cannot be followed in forecasting rain, for the reason that the distance from the centre of the storm is very uncertain, and often there is no rain to the southeast. The only safe rule to follow is to locate, as near as possible, the position and extent of rain areas which have already begun on successive maps. Oftentimes when scattered light rain has occurred in any region one feels very certain that rain is sure to occur at some points; but it is much safer not to try to predict the particular localities, but to leave out the rain prediction, for the reason that one is just as likely to put the "rain" exactly where it does not occur, and the "fair" just where it rains. This is especially

the case west of the Mississippi River, and wherever there is not much rainfall.

Northerly Currents Meeting Southerly. — There is a single partial exception to the rule that rain cannot be predicted on general principles, and this is when there is foreseen a marked movement of the air from both north and south areas toward each other. This occurs when a high area hovers over the Southern States, and a partial trough is formed with another high to the north. Under these conditions, which ordinarily might be anticipated to give the clearest weather, clouds will frequently arise and light rains will fall. Even here, however, great caution is needed, and it is generally safer not to try to forecast rain unless one has seen rain already falling. This is especially the case in the colder months of the year.

Loci of Storms. — It will be found that at certain times there is a remarkable persistency in the occurrence and beginning of storms in certain well-defined localities. One of the best marked of these is in west Texas, another is over Lake Michigan still another over North Carolina. The latter often moves to the Middle Atlantic coast. In such cases storms seem to hover around these loci ; oftentimes rain will emanate from a low area and spread over the whole country without any motion whatever of a low-pressure area. Such rains are the most difficult of all to predict, and occur usually at a time when the upper movement of the whole atmosphere is very much diminished. In fact, it may be laid down as a general rule that when there is a rapid movement of storms and high areas across the country the weather and temperature are far easier to predict than when this movement slows down. In the former case, storms are much more likely to clear up clean, and not leave straggling showers, the temperature, especially, runs in much more marked contrasts, and its changes are far easier to forecast.

Rainfall on the Gulf Coast. — Rain on the Gulf coast does not follow any rules at all except that if it has begun seemingly in the centre of a fair condition one cannot with safety predict anything but showers, and continue this prediction until the rain has ceased. This is especially true of Florida. A remarkable weather condition sometimes prevails on the Gulf, and this has not, as yet, been thoroughly studied. During times of prolonged drought in the Gulf States it will be found that rain

is often much more likely to occur in the interior than on the immediate coast. This is especially true in hot summer weather. On the immediate Lake shore it is generally safe to predict showers on the approach of well-marked low areas, though even this is not an invariable rule.

Surest Conditions for Fair Weather. — There are certain remarkable conditions under which one is always safe to predict fair, even though the skies are very threatening and a strongly marked low area is advancing. These conditions are when a high area of great magnitude moves south or southeast from the northwest and is followed in the extreme northwest by a low area of seemingly great intensity. Often the barometric gradient becomes steep enough to give winds of forty and fifty miles per hour, and everything betokens a very severe storm. Nevertheless no rain is likely to occur in front of the storm, and this condition will continue until the high area begins to give way and the southerly wind dies down to almost a calm ; after that rains may be expected, especially in the Lake regions and on the Atlantic coast. This condition, however, must be carefully distinguished from another which at first sight seems analogous, but which gives entirely different results. This is when the high area in front of the storm takes an easterly trend, the winds from the latter are more easterly and cooler, and as a consequence rain immediately begins in the Lake regions, and persists for a long time, or until the storm has completely passed over, or the high area has finally taken a southerly tendency.

Rain in High Areas or the Rear of Storms. — A rather remarkable accompaniment of these conditions just described is the occurrence of rain in the rear of the storm. This is one of the safer predictions to make, although seemingly directly contrary to all the principles of forecasting to which one becomes accustomed in the East. In the Atlantic States it is well known that while the storm is still to the westward southerly winds spring up, bringing more or less rain, but after the low area has passed by rather strong and very dry, cold, west and northwest winds come in and the sky clears almost immediately. On the contrary, in the West the warm southerly winds are very dry and no rain occurrs in front of the storm, while the cold west winds bring on rain which frequently

persists even to the centre of the high area. It seems probable that the proximity of the Atlantic Ocean in the former case and of the Pacific in the latter may account for these differences. The movement of the clouds in the rear of the western storm is from the Pacific, as may be seen readily on the cloud chart, and this indicates a tendency for moist currents from the Pacific to blow into the rear of the storm. Gen. Greely has suggested that moist currents from Hudson's Bay may also blow to the north of the storm and then circulate to the rear. Many more stations to the north and west will be needed to satisfactorily account for this anomaly. It is well known that in Europe more rain falls in the rear than in the front of storms, and in this case the oceas lies to the westwards.

Rising Pressure to the South. — Gen. Greely, in "American Weather," has suggested a rule that when the pressure begins rising to the southwest it will shortly clear away in regions towards the northeast, if it has been raining or threatening there. This rule is true in any part of the country, provided there is a sort of spontaneous rise in the pressure; I mean a rise not accompanied by a high area; but if a high area pushes south, and the pressure rises on that account, the winds must first get well into the southwest and rather strong before the sky will thoroughly clear.

Verification of Weather Predictions. — It is well recognized that in a month when rains are frequent and when they are more or less spontaneous, that is, when they do not accompany well-marked storms, it is very much more difficult to forecast the weather than in other months when there is a strong persistency towards fair weather. The public, however, lose sight of these facts, and are inclined to measure the ability of one in making forecasts by the percentage which is accorded in his month. This may be partially obviated by allowing for the rains in any month. In any case, however, the true method of verifying a prediction would seem to be by experts from the map on which the prediction was based rather than on the resulting weather.

Local Forecasts. — It seems probable that a wrong impression has gone abroad regarding the errors which arise in making forecasts at the central office in Washington. It is thought by many that serious failures have occurred from neglecting local

signs. It can be shown readily that ninety-five per cent of the errors are due to rapid changes in the greater or more general movements of the atmosphere, and not to the neglect of local causes. These greater movements may be more carefully studied at a central office by experts than by local forecasters at their stations. There is a slight advantage which the local forecaster has, in that he can make his prediction three hours later than the main office, but aside from this there would seem to be a greater advantage at the central office than on station.

THE EFFECT OF TOPOGRAPHY UPON THUNDER-STORMS.

RALPH S. TARR.

IN the May number of this JOURNAL the statement is made on page 27, that it seems unreasonable to suppose that topography should have any appreciable effect upon the direction of motion of thunderstorms, since these are phenomena upon too large a scale to be so affected. This statement is made in answer to suggestions from observers who note the apparent fact of coincidence of thunderstorm motion with marked topographical features.

At first thought it seems as if it must be true that topography can have no marked effect upon the direction of the path of a thunderstorm. During the past spring I have had opportunity to study the effect of topography upon the path of thunderstorms, and in this brief paper shall attempt to show that in some cases at least the direction of motion of these storms is directly dependent upon the topography.

At Ithaca, N. Y., the university buildings are placed upon the hillside, several hundred feet above the bottom of the valley in which is situated Cayuga Lake. From the university buildings one can look down upon this broad valley, which is a mile or more in width at this point, which is at the head of the lake. One can see down the lake for a distance of five or six miles and up the valley an equal distance. This valley continues with nearly its normal width for many miles above the head of the lake, and is occupied by the lake for a distance of fully thirty miles. From the college the view westward shows

a gently sloping hillside rising to an elevation of seven or eight hundred feet, at a distance of several miles.

In May and early June the conditions for the formation of thunderstorms were particularly favorable, and the region was visited by many. From the west side of McGraw hall I watched several of these storms form, and as long as they were distinctly visible noticed their path of motion. Some of the storms came from the other side of the divide, somewhere beyond Seneca Lake, in all probability. These were well-developed storms, and travelled without any regard to topography.

In other cases I was able to observe the beginning of the storm upon the western side of Cayuga valley. At first a light cloud formed, then a little rain fell, at first not enough to obscure the view beyond. Rapidly the storm would grow in intensity and extend its area, at the same time commencing to move. In all cases the movement was down the hillside into the lake valley, and usually the movement was slightly diagonal to the direction of the valley. Whenever the movement was at right angles to the valley the storm was not deflected, but if, as was usually the case, the direction was from the northwest, the storm was deflected by the eastern wall and the path was up the valley.

These storms were apt to begin on any part of the hillside, but they were most numerous and became much more violent when they began in the valley of Enfield gorge, a tributary from the west, which enters slightly diagonal to the course of Cayuga valley. Although only a few miles from Ithaca, I have seen storms of considerable intensity form here, and travel up Cayuga valley without reaching Ithaca. That is to say, they seemed to follow the Enfield gorge, and upon reaching Cayuga valley, striking it diagonally, veered to the south, and continued this course as long as they were in sight.

Several storms, the origin of which I could not see, swept up the lake, and followed the valley very closely. Indeed it is a matter of common belief in that vicinity that thunderstorms in general are more numerous in the valley than on either side and that their course is determined by the valley. It is further believed that storms travelling up the lake reach the head of the valley, and, being deflected, return again. Of this I saw no evidence, however, and I very much doubt if it can be proved.

While the storms which I have studied are by no means of the largest and most violent types, yet they very frequently became well-developed storms, lasting for an hour, and accompanied by violent rains and heavy thunder.

On the plains of Texas, where whirls of sand are very common, rising to a height of several hundred feet, I have frequently noticed the effect of topography in changing or originating the path of motion, and in the Gaudalupe Mountains in West Texas I have seen storms apparently moving down the valley of McKitterick cañon, as if their course were determined by this marked topographic feature.

These observations lead me to believe that topography has a decided effect upon the path of thunderstorms when they are beginning. In other words, that the initial direction is determined by the topography provided the topographic diversity is sufficiently marked. When, however, the storm has assumed sufficient size to become a phenomenon of the upper air rather than a local storm topography in all probability has very little effect upon its motion. It therefore seems to me that there is more reason in the popular belief that topography guides the path of thunderstorms than is commonly believed by meteorologists. At least in the region of Cayuga Lake there seems to be no doubt that this effect is produced, and, although the conditions are particularly favorable there, it seems probable that there are many other places equally favorable, and that the phenomenon simply needs study for verification.

ITHACA, N. Y., JULY, 1892.

CURRENT NOTES.

THE MAURITIUS HURRICANE OF APRIL 29, 1892.

From the special overland editions of the "Merchants' and Planters' Gazette," published at Port Louis, Mauritius, on May 11 and 12, we take the following extracts with reference to the hurricane of April 29. The account is by Dr. Meldrum, the director of the observatory: —

The hurricane which raged for a few hours yesterday, the 29th of April, has in many respects been unprecedented in Mauritius.

Never till now has the island been visited by a hurricane at any time between the 12th of April and the 1st of December. Hitherto the hurricane season of Mauritius has been supposed to begin on the latter and to end on the former day, and till yesterday there has been no exception to the rule. Nor was there any sign of danger till yesterday, when the barometer began to fall rapidly and the wind to increase to a heavy gale. The suddenness, rapidity, and extent of the changes which took place in a few hours are unparalleled in the annals of the colony.

The following table will for the present suffice to convey some idea of the changes which took place in the barometric pressure and the direction and velocity of the wind from 9 A. M. on the 24th to 9 P. M. on the 29th.

Day and Hour.	Barometer.		Wind.	
	Corrected and Reduced to Sea-level.	Fall or Rise Per Hour Corrected for Variation.	Mean Direction.	Velocity in Miles Per Hour.
	Inches.			
April 24, 9 A. M. . . .	30.059	. . . . .	E. S. E. ½ S.	8
" 27, 9 " . . .	29.903	. . . . .	E. by S.	15
" 28, 9 " . . .	.905	. . . . .	N. E. by E.	12
" " 4 P. M. . . .	.816	— .003	N. E. by E.	14
" " 9 " . . .	.850	— .006	N. E.	12
" 29, 6 A. M. . . .	.660	— .018	N. E. by E.	22 4
" " 8 " . . .	.630	— .029	N. E. ½ E.	34.7
" " 9 " . . .	.576	— .063	N. E. by E.	35.0
" " 10 " . . .	.480	— .094	E. N. E. ½ N.	40.0
" " 11 " . . .	.338	— .131	N. E. by E.	52.0
" " noon	.066	— .251	N. E. ½ E.	68.0
" " 1 P. M. . . .	28.517	— .532	N. E. ½ E.	96.5
" " 2 " . . .	27.990	— .513	North.	56.0
" " 3 " . . .	28.084	+ .048	W. N. W.	68.0
" " 4 " . . .	.520	+ .483	W. S. W.	112.0
" " 5 " . . .	29.059	+ .529	S. W.	82.0
" " 9 " . . .	.719	+ .151	S. Wrd.	26.0

In the above table the fall or rise in the barometric pressure is corrected for the daily variation, and from 9 A. M. on the 24th to 9 A. M. on the 29th

the mean hourly velocities of the wind are given, whereas from 10 A. M. to 5 P. M. on the 29th the rates of the velocity per hour are given as obtained from observations taken during intervals of two to five minutes.

It will be seen that at 2 P. M. on the 29th the barometer was at 27.990 inches; that from noon to 2 P. M. it fell 1.045 inch; that from 3 to 5 P. M. it rose 1.012 inch; and that from 5 to 9 P. M. it rose .660 inch. The absolutely lowest pressure was 27.961 inches at 2.30 P. M., which is the lowest on record in Mauritius.

From 9 A. M. on the 28th to 1 P. M. on the 29th the mean direction of the wind did not vary much, but it occasionally showed a tendency to veer towards North, being at times from N. E. b. N. to N. N. E. Between 1 and 2 P.M. it on the whole veered to North, and between 2 and 3 P. M. to W. N. W., oscillating considerably, and soon after settling down at W. S.¾W.

After 11 A. M. the velocity of the wind increased much, being at 1 P. M. at the rate of 96.5 miles an hour and at 1.20 at the rate of 104 miles. But from 1.25 to 2.30 P. M. there was a lull; the velocity decreasing to the rate of 43 miles an hour at 2.33 P. M. It then began to increase again, and at 3.47 P. M. was at the rate of 121.2 miles per hour, but it soon began to abate being at the rate of 72 miles at 5.20 P. M., 60 miles at 6 P. M., 47 miles at 7 P. M., and 26 miles at 9 P. M. By this time the weather was fine, the sky partially clear, and here and there stars shining brightly.

Seeing that from 9 A. M. on the 24th to 9 A. M. on the 27th the barometer had fallen from 30.059 to 29.903 inches, and that the wind, though light, had veered from E. S. E. ½ S. to E. b. S., a note was sent to the newspapers on the latter day stating that there was heavy weather to the Northward and that it had existed since the 24th; which, as usual in such circumstances, meant that there were indications of a cyclone away to the Nrd, and that it was travelling from N. Erd to S. Wrd.

But the wind having by 9 A. M. on the 28th reached N. E. b. E., and the barometer being higher on the 27th at the same hour, there was no apprehension; and in the afternoon of the 28th, the wind being still moderate from N. Erd, and the barometer falling at the rate of only .003 inch per hour, it was announced that there was no fear.

As already stated, it was only on the 29th that the conditions became unfavorable, and at 9.40 A. M. a telegram was despatched announcing that the barometer was falling at an accelerating rate. Other telegrams, despatched at 11 A. M., announced that the velocity of the wind was at the rate of 52 miles an hour in the squalls, and that probably it would not exceed 56 miles an hour.

Soon afterwards the telegraph wires were broken and all communication ceased. The barometer continuing to fall at an accelerating rate, and the mean direction of the wind being nearly constant, it was inferred that the centre of the depression would, contrary to long experience the wind being from N. E., pass over the island, and that the wind would then come from nearly the opposite direction. The centre, however, did not pass over the observatory, but over a point about 8 miles to the Wrd of it, and apparently from that point it travelled across the island on an E. S. Ely course.

As a rule, when the wind is from N. Erd, there is scarcely any danger of

a hurricane in Mauritius. All our great hurricanes have commenced, not with a N. Ely, but with a S. Ely wind; and this is why, when the wind was from N. E. b. E. at 11 A. M. yesterday, and the barometer at 29.338, it was considered probable that the velocity of the wind would not exceed 56 miles an hour. On the 12th of February last the barometer fell to 29.325, and the greatest velocity of the wind was 47.5 miles per hour from N. E., the barometer soon afterwards rising and the wind decreasing.

There are, apparently, only two ways of, in a measure, accounting for the passage of the centre of a hurricane over the island yesterday from W. N. Wrd to E. S. Erd. Firstly, the cyclone, which had been travelling to the Nrd and N. Wrd of the island on a S. Wly course, from the 24th to the 27th, recurved to the Srd and S. Erd; or secondly, a small secondary cyclone, which was generated in the S. E. quadrant of the larger cyclone, travelled to the E. S. Erd., and bore down on Mauritius. The latter is perhaps the more probable hypothesis; for the small but violent hurricane of yesterday, with respect to its extent, duration, etc., exhibited the characteristics of a local atmospheric disturbance.

On the night of the 27th and morning of the 28th there was a great deal of thunder and lightning, and also frequent lightning during the night of the 28th. But the hurricanes of Mauritius are seldom, if ever, immediately preceded by thunder and lightning. It may be stated, also, that from the 25th to the 29th there were from five to six groups of sun-spots, indicating a considerable increase of solar activity; and that from the 25th to the 28th there were large magnetic disturbances, the portion of the sun's disc on which there was a very large group of spots on the 12th of February being again on or near the sun's central meridian.

Fifteen years ago I prepared a list of all the hurricanes and gales which, as far as could be ascertained, had been experienced in Mauritius from 1759 to 1877.

From that list, which is given in Kyshe's Almanach for 1878, it will be seen that the dates of all the known hurricanes and gales experienced in April, with the lowest barometric pressures, and the directions and maximum force of the wind, are as follows: —

Years.	Days of Month.	Lowest Barometer.	WIND.		Remarks.
			Direction.	Press in Lbs. on Sq. Ft.	
		Inches.			
1773	9th	?	?	?	Hurricane.
1814	19th	29.343	N. N. E.	?	Strong Gale.
1824	11th	29.138	S. E. b. E. to N. E.	?	Hurricane.
1830	4th	29.485	?	?	Strong gale.
1833	10th	29.547	South.	?	Strong gale.
1834	30th	29.822	S. E. to E. & N.	?	Strong gale.
1840	10th	28.965	S. E. to E. & N. W.	?	Hurricane.
1855	30th	29.921	E. S. E. to N. E.	17	No damage.
1856	3d to 6th	29.631	S. E. to S. & S. W.	24	–
1866	13th to 19th	29.825	S. E. to E.	13	–
1867	9th to 14th	29.762	S. E. to S.	13	–
1870	4th to 8th	29.801	S. E. to N. E.	16	–

In all there were, from 1759 to 1877, three hurricanes and nine gales in April. The hurricanes occurred respectively on the 9th of April, 1773, the 11th of April, 1824, and the 10th of April, 1840. The lowest barometric pressure in 1773 is not known, but in the two other hurricanes it was respectively 29.138 and 28.965 inches. From 1853 to 1867 the pressure of the wind was registered by an anemometer, and during that period the greatest pressure in April was 24 lbs. per square foot, on the 4th of April, 1856. Since 1870 there has been no gale in April, the greatest velocity of the wind in that month having been only 31 miles an hour on the 4th of April, 1877.

There have been gales in Mauritius even in May and June, but no hurricane. On the 7th of May, 1868, the barometer fell to 29.710 inches, with the wind from S. E. to East, and the maximum pressure was 16 lbs. to the square foot. On the 21st of June, 1860, there was a pressure of 18lbs. with the wind from South. But, as far as is known, there has never been a hurricane in Mauritius between the 12th of April and the 1st of December, till the 29th of April, 1892.

As to the other months of the year, the lowest readings of the barometer and the directions and force of the wind, in the severest of our hurricanes, were as follows : —

Years.	Month and Days.	Lowest Barometer.	WIND.	
			Direction.	Press in Lbs. on Sq. Ft.
		Inches.		
1818	March 1	28.000	S. S. E. to N. E. & N. W.	?
1819	Jan. 25	28.782	S. S. E. to S. W. & W.	?
1824	Feb. 23	28.161	S. E. to E. N. E. & N. W.	?
1828	March 6	28.517	S. E. to E. & N.	?
1836	March 5	28.114	S. E. to E. & N. W.	?
1848	March 8	28.790	S. E. to E. & N. E.	?
1861	Feb. 16	29.041	S. E. to E., N., & N. W.	45
1868	March 12	28.813	S. E. to E., N., & W.	50
1874	March 27	28.665	S. E. to E., N., & N. W.	36
1879	March 21	29.032	S. E. to E., N., & N. W.	40

In all these, and other hurricanes, the wind began to increase from the S. Erd, whereas in the hurricane of the 29th ultimo it began to increase from the N. Erd. The lowest barometric pressure was 28.000 inches on the 1st of March, 1818. But on the 29th of April last the barometer fell to 27.961 inches at sea-level, and the maximum pressure of the wind for 5 minutes was 73 lbs., corresponding to a velocity at the rate of 121 miles an hour.

There are only two instances on record of a cyclone having approached the island from the N. Wrd.

One of these cyclones occurred in January, 1863, and the other in January, 1868. In the former, the barometer fell to 29.231 and in the latter to 29.512 inches, and very little damage was done.

In my last communication I gave the rates of the velocity of the wind per hour as observed for intervals of two to five minutes. Since that time the mean hourly velocities, as deduced from the anemogram, have been deter-

mined. From 10.30 to 11.30 A. M. (on the 29th of April) the mean velocity for one hour was 50.6 miles. It then increased to 89 miles from 0.30 to 1.30 P. M.; decreased to 65 miles from 1.30 to 2.30 P. M.; increased to 103.3 miles from 3.30 to 4.30 P. M., and then decreased to 50 miles from 6.30 to 7.30 P. M. A velocity of 103 miles represents a pressure of 53 lbs. on a square foot. It has been reported that on the day of the hurricane balls of fire (electricity) were seen in different parts of the island.

*The Study of Meteorology in the United States.** — In 1883 Dr. Frank Waldo, then in the employ of the U. S. Signal Service, presented a report on the extent to which meteorology was taught in the higher schools of Germany, Switzerland, and Austria, in which he refers to the growing need of trained meteorologists in this country, and says: "We have a few men only who have made this subject enough of a study to be able to give instruction to young men. We have not more than two or three schools where there is any pretence of teaching meteorology, and even then the instruction is of a very elementary nature."

Of late increased interest has been manifested in regard to meteorological education in the United States, chiefly, it is to be presumed, on account of the extension of the weather service of this country and of its practical applications. Young men of trained ability are in demand for the work of the service, and the increased distribution of weather maps and forecasts has drawn much attention to the subject. To enable the public to fully profit by the information thus conveyed, there is needed just such a widespread awakening in the matter as is now apparent.

I have repeatedly been asked within a short time past, both here and by letter from abroad, what is being done in our higher institutions of learning in the way of instruction in meteorology. To answer these numerous inquiries and to obtain definite information, which I am sure will be of general interest, I have, through the courtesy of the Commissioner of Education, caused a systematic examination to be made of the college catalogues on file in his office, and the results are presented herewith. It should be borne in mind that the courses announced are in general of a somewhat elementary character. Original research and the work carried on by the trained meteorologist are usually freed from the restrictions of a class. In one case, however, which has come to my notice, admirable work of an advanced character is being carried on in class.

Following is a list of the universities and colleges announcing definite courses in meteorology. Such further information found in the announcements is given as is consistent with brevity: —

California.—University of California, Oakland, John Le Conte, professor of physics. The physics of meteorology, lectures on the distribution of heat over the earth's surface, permanency of climate, distribution of rain, winds, etc., and on optical phenomena of the atmosphere. Twice a week during the second semester.

* Reprinted from Report of the Chief of the Weather Bureau for 1891.

Colorado.— State Agricultural College, Fort Collins, Louis G. Carpenter, professor of physics and engineering. Meteorology is taken up for six weeks during the second term of the senior year, and includes a discussion of the instruments used in taking observations, barometry, thermometry, precipitation, the laws of storms, and the elements of agricultural meteorology.

Connecticut.—Yale University, New Haven, Conn. (Catalogue 1889–90). A course in meteorology is given the seniors twice a week during the second semester. Loomis' Meteorology is used, with daily study of the current weather maps. In the Sheffield Scientific School of this university, in the course in agriculture, two hours per week (lectures) of the first half of the senior year are devoted to meteorology.

Florida.— Florida Agricultural College, Lake City. In the senior year, spring term, meteorology divides the time with logic, tactics, and astronomy.

Indiana.— Purdue University. In the second term of senior year of School of Agriculture meteorology is taught two hours a week for eight weeks.

Iowa.— Iowa State Agricultural College. Meteorology is given once a week in the second half of the senior year.

Kansas.— (1) Kansas State Agricultural College, Lake City. Physics and meteorology, two terms' work; text-books, Atkinson's Ganot's Physics and Loomis' Meteorology. This course also includes a careful study of instruments and methods employed in taking meteorological observations. (2) University of Kansas, Lawrence, Francis H. Snow, president and professor of botany, entomology, and meteorology. Meteorology: Loomis' Treatise and Lectures, one half semester.

Massachusetts.— (1) Harvard University, Cambridge, William M. Davis, professor of physical geography. Meteorology: Lectures, recitations, written exercises, and laboratory work, three times a week during the first half-year. A course of equal extent in physical geography follows during the second half-year. A second course in physical geography and meteorology consists of lectures and reports twice a week for a half-year. (2) Massachusetts Agricultural College, Amherst. Freshman year, fall term, climatology, or relations of weather and farming, two hours a week. (3) Massachusetts Institute of Technology, Boston, William H. Niles, professor of geology and geography. Climatology is taught, by lectures and recitations, twice a week for fifteen weeks of the senior year. The course is introduced with a general outline of meteorology, and in the physical laboratory the students have some practice with the ordinary meteorological instruments.

Michigan.— (1) Albion College, Albion. In the fall term a course of three hours a week in meteorology and the mechanics of the atmosphere is given in the department of physics. (2) Michigan State Agricultural College, R. C. Kedzie, professor of chemistry. A course in meteorology is given by lectures five times a week during the spring term of the senior year. (3) University of Michigan, Ann Arbor. A course in modern meteorology is given twice a week during the first semester; instruction is given by lectures, recitations, and practice in forecasting by means of weather maps.

Nebraska.— Doane College, Crete, G. D. Swezey, professor of natural sciences. Meteorology and mineralogy constitute a course given in the

winter term (three months). In meteorology there is text-book work supplemented by observations with the instruments of the observatory and by the tracing of weather changes from the United States weather maps.

New Hampshire.— New Hampshire College of Agriculture and the Mechanic Arts; Dartmouth College, Hanover. Second year, third term, Loomis' Meteorology.

New York.— Alfred University, Alfred Center, H. C. Coon, professor of physics, gives a course of ten weeks in theoretical meteorology, and another of like extent in meteorology theoretical and practical.

North Carolina.— Davidson College, H. L. Smith, professor of natural philosophy. Astronomy and meteorology are given three times a week in the senior year. After the 1st of March the class studies meteorology, and is taught to handle a full set of instruments for determining air pressure, temperature, moisture, rainfall, etc. Loomis is used as a text-book.

North Dakota.— University of North Dakota, Grand Forks, Ludovic Estes, professor of mathematics, physics, and astronomy. Meteorology is taught one hour per week during the senior year of the scientific course. Loomis's Treatise, or an equivalent, is used.

Ohio.— Findlay College, Findlay, A. C. Redding, professor of chemistry and physics. In the fall term of the junior year meteorology is given in a course of lectures embracing atmosphere, winds, clouds, precipitation, theory of storms, atmospheric electricity, climatology, etc.

Oregon.— Oregon State Agricultural College. Meteorology is taught during the winter term of the junior year.

Pennsylvania.—(1) Pennsylvania State College. In the course in agriculture meteorology (Abercromby's Weather) is given three times a week during the third term. (2) Washington and Jefferson College, Washington, James F. Ray, professor of physics and chemistry. Meteorology (Loomis) is taught during the third term of the senior year.

South Dakota.— University of South Dakota, Vermilion, Lewis E. Akely, professor of physics and chemistry. A course in meteorology is given two hours per week during winter term. Lectures and practical work.

Wisconsin.— University of Wisconsin, Madison, F. H. King, professor of agricultural physics. In the College of Agriculture a full course (five times per week) in meteorology is given during the fall term.

Wyoming.— University of Wyoming, Laramie. During the fall term of the College of Agriculture a course is given in meteorology and the use of instruments. The instruments are at the agricultural experiment station in connection with this college.

There are of course many institutions where more or less instruction in the elements of meteorology is given under some other name. In physics the topics of atmospheric pressure, vapor tension, condensation, and others relate directly to this subject. It is not unusual for a chapter on meteorology to be added to a text-book of physics, and in a general course in physics of sufficient extent the subject may properly come in for its share of attention. In physical geography, also, no general course would be complete which did not include the subject of climatology and theoretical meteorology.

Besides the above-named colleges, about twenty incidentally mention

meteorology usually as included in the general instruction in physics or in physical geography. Four have weather-service stations in connection with them, and offer opportunities for practical meteorological work. Two or three other colleges announce their intention of soon including meteorology in their curricula.

It should be remembered that the Bureau is doing much in the way of popular education in meteorology by means of its maps and the work of individual employees, but allusion has been made to this elsewhere.

*Clouds in Thunderstorms.** — The thunderstorms of June 14 and 17, 1892, as seen at Cambridge were of especial interest from the distinct development of certain cloud forms that accompanied them.

The storm of the 14th was much more severe to the north of Cambridge; we saw the southern part of its cirrus overflow late in the afternoon; at six o'clock a more distinct cirrus margin passed overhead, the forerunner of the great cirro-stratus sheet that spread out from the storm area. At 7.02, a lively, dusty breeze reached us, although no rain came till about 7.25, the force of the storm having passed north. About 7.10 to 7.15, the zenith was occupied with a great variety of descending or inverted cumulus clouds, settling down, as if they had toppled over from an ascent elsewhere, writhing and twisting as they entered the lower air, and progressively dissolving away as they descended. When their descent brought large volumes of cloud above us the sky was darkened; but as the cloud dissolved away the light increased, leaving only the high cirro-stratus cover overhead.

It appears to me that this is a part of the convectional overturning of the atmosphere, on which thunderstorms depend; the air ascends and becomes cloudy in the central area, yielding rain when a large cloud mass has been formed; the lofty part of the overflow forms the cirro-stratus cover, floating far eastward in advance of the storm clouds, and thus indicating the existence of faster upper currents. The lower members of the forward or lateral overflow form the inverted cumulus clouds, here described.

The storm of June 17 gave an excellent illustration of two subordinate parts of the cloud mass: first, the ragged under edge of the great cloud mass; second, the gray squall cloud, a little farther back from the margin of the storm. As before, the cirro-stratus cover of the storm floated far eastward and southeast of the storm centre. Descending and dissolving inverted cumuli preceded the arrival of the rain cloud. During this time a westerly breeze prevailed. Just at 3 o'clock I saw three flags to the north, flying in honor of Bunker Hill day, blowing straight to the south. As the town-clock struck three the wind changed its direction over the trees in front of me; and then three wind vanes a short distance to the south swung around from west to north; all marking in the most perfect way the arrival and passage of the out-blowing squall beneath the storm. Now within a few minutes of this change of wind the two cloud edges passed overhead. One appeared dark against the lighter upper cloud sheet; its front ragged edge was plainly seen to be formed by the thickening and

* Reprinted from the Bulletin of the New England Weather Service for June, 1892.

clotting together of inflowing wisps of cloud, marking that part of an inflowing current where its temperature was reduced to that of condensation of vapor to cloud. The cloud thus formed floated southward, or southeastward, moving towards the inflowing, damp, and clouding indraught.

The second cloud edge soon followed; it was grayish, apparently lighter than its predecessor, although this may have been the effect of contrast. As it floated along, borne by the general movement of the storm drift, it was seen distinctly to roll backwards; that is, its southern front ascended and rolled over to the north, while its under part moved forward.

It is plain that such backward rolling cannot be compared to the forward rolling often seen in fair-weather cumulus clouds, in which the top rolls in the direction of motion. The case here described appears to be an illustration of the process that I have suspected for some time, but which until now I never saw clearly at work, namely, a rolling motion formed between the general inflowing, ascending current of the storm cloud and the outflowing squall wind beneath. The indraught is much the larger of the two; the whole storm depends on the condensation of vapor in this wind during its ascent and expansion. The outflowing squall, as explained by Ferrel, results from the downward pushing of the great expanding mass of air above; and the gray squall cloud is formed in a roll between the two.

The rain of thunderstorms generally follows the passage of the squall cloud by a few minutes. Before its arrival the observer often has an opportunity of seeing the approach of the squall cloud and of noticing its peculiar motion. I should be glad to learn if others have noticed the contrast between the dark lower cloud edge of the great cloud mass and the gray squall cloud, as here described, and if they interpret the differences as here suggested.

W. M. DAVIS.

Canadian Meteorological Service.— The report of the Department of Marine (Ottawa) for the fiscal year ended June, 1891, contains a report upon the Meteorological Service of Canada for the period extending from Oct. 1, 1890, to Oct. 31, 1891. This service is divided into two branches: (1) the collection and utilization of observations taken simultaneously for the purposes of weather prediction, and (2) the reduction of observations taken by volunteer observers and others for climatological purposes. The publication of the results obtained from the second division has been continued annually from the establishment of the service in 1872; but it is now proposed to deal with the accumulated observations, and to publish them in a serviceable and readable form. This will be the first authoritative Government publication on the climate of Canada; and it will be useful for immigration purposes, and for showing the suitability of the climate in various localities for raising agricultural crops. It is expected that the work will require three years to complete. Among the stations in connection with the Canadian Service is one at Bermuda, towards the maintenance of which an annual contribution is paid by the government of that island, and cable messages are received daily in the interests of shipping on the Atlantic coast. The Cable Company transmits the messages at half the ordinary

rates. Many severe storms have occurred in Canada since the last report, and in each instance warnings were issued from Toronto; of these 80.7 per cent are stated to have been verified. Warnings of approaching snowstorms were also issued to railways, and it is proposed to extend this service to Manitoba, and as far west as Qu'Appelle. — *Nature.*

Thunderstorms in Wisconsin in May, 1892.* — Between May 15 and 31 thunderstorms were reported 76 times from reporters located in different towns. The greatest number reported on one day was 20 on the 18th; on the 25th, 19 were reported and on the 26th, 12. Those of the 18th and 26th occurred during the passage of low-pressure areas, but those of the 25th occurred when a marked high-pressure area was central over the State, temperature quite equally distributed and about 5° below the normal, and gentle northerly winds blowing. Such conditions are generally supposed not to be favorable to the development of thunderstorms, yet they were frequent in nearly every part of the State, reports being received from nineteen towns. However, it must be stated that cloudiness was general throughout, and that the barometer was slowly falling during the day, the average fall being about .08 during the twelve hours ending at 8 P. M., for the whole State, and .18 for the twenty-four hours ending the next morning at 8. A. M. The decrease resulted in placing a low-pressure area over the State before the following noon which became a general rainstorm. On the evening of the 25th reports from telegraphic stations in and on the borders of the State showed only a trace of rain at Duluth and St. Paul. Without the recently inaugurated system of reporting these storms, their occurrence would have been unknown until the receipt of reports from voluntary observers at the end of the month, and then the information would have been much less complete.

Of 59 reports of storms, 16 show them to be moving towards the northeast, 15 east, 10 southeast, 10 northwest, 4 north, 3 southwest, and 1 south.

Of 66 reports, 44 showed the beginning of the thunderstorm to be between 12 noon and 6 P. M., 9 between midnight and 6 A. M., 7 between 6 P. M. and midnight, and 6 between 6 A. M. and noon. It will be seen that 66⅔ per cent of all storms reported occurred near or during the time of maximum daily heat.

Of 51 storms, the average duration of thunder is 43 minutes, the greatest period 2 hours 30 minutes, and the least less than one minute.

Of 52 storms, the average duration of rainfall is 1 hour, 32 minutes, the greatest period 7 hours, and the least probably one minute.

Of 27 storms, the average rainfall is .33 of an inch, the greatest 1.20, and the least a trace.

Of 30 storms, the average difference of temperature readings taken before and after is 2.8 degrees lower, the greatest difference 20 degrees, and in two cases the temperature showed a slight rise.

* From the Wisconsin Weather and Crop Journal, July, 1892.

Climate of the British Isles. — Mr. R. H. Scott has contributed an article, entitled Notes on the Climate of the British Isles, to "Longmans Magazine."

The author gives some amusing instances of the distortion of facts at seaside stations, where the observers are anxious to prove the advantages of their own towns over those of their rivals. Taking the whole year round, the warmest spot is the Scilly Isles, which are a degree warmer than either the west of Cornwall or the Channel Islands, while the coldest region on the coast is the extreme northeast of Aberdeenshire. In winter very little difference of temperature is met with all along the east coast; but the coldest part of England lies around the Wash. With regard to the variability of temperature, or the difference of the mean temperature of an entire day, the equability of the temperature of these islands is very great. The only locality for which a more uniform temperature has yet been published is Georgetown, Demarara; the figure for this place is 1.1°, while for London it is 2.7°. All the great changes of temperature occur in winter, and accompany sudden thaws. As regards bright sunshine, the Channel Islands are by far the most favored. On the mean of the whole year, Jersey secures thirty-nine per cent; but from the Bristol Channel to the coast of Norfolk there is but little difference in the amounts recorded. In cities like London the deficiency is due to smoke. The statistics relating to fog are not yet completely discussed, but so far as they go they show that in winter the foggiest district is the east coast of England. Next come London and Oxford, which are about equal. With regard to rainfall, the east coast stations receive, on an average of the whole year, about half as much as those on the west coast, the amount being about twenty-five inches on the east coast, thirty to forty inches between Sussex and Devonshire, and fifty inches to the south of Cornwall. In the west of Ireland the amount rises to seventy or eighty inches, owing to high land near the coast. The driest hour almost everywhere is noon. — *Nature.*

Rise of Temperature in a Chinook Wind. — In a recent number of the "Monthly Weather Review" Mr. E. B. Garriott mentions a remarkable rise of temperature which occurred in connection with a Chinook wind in the northwest on Jan. 19, 1892. The thermograph curve at Fort Assiniboine, Mon., showed a rise of about forty-three degrees in fifteen minutes, and a rise of about forty-nine degrees in less than three hours.

CORRESPONDENCE.

A THEORY FOR MAKING ANNUAL FORECASTS OF THE WEATHER.

Editor of the American Meteorological Journal: —

By the advice of the Chief of your Weather Bureau at Washington, I send you a brief statement of my weather theory for making annual general forecasts of the weather, in the hope that some of the many competent meterological readers of your valuable JOURNAL will give it a friendly criticism. It is as follows: —

I have made an approximate calculation that the speed of the Arctic current, which is the reflux of the Gulf Stream, from the Arctic Ocean to its contact with the Gulf Stream off the coast of Newfoundland, *averages* about ten miles in a day of twenty-four hours. Consequently field ice, which begins to form far within the Arctic circle by the 20th of September, *can and does* arrive at the Gulf Stream, in the pathway of ships, in a period of one hundred and fifty days, or about the 20th of January. My observation of the facts for a period of fifteen years goes to prove that there is a *considerable variation* in the time of arrival. Very early, say about the 20th of January, average time the 15th of February, and very late, about the 20th of March, — a variation of two calender months. Now, as the speed of the Arctic current is ever the same, it is evident that these variations in the time of the arrival of the ice field must be due to the atmosphere, or, in a word, to winds varying from *light to medium and very strong*.

Now, as the winds from Labrador and the more northern parts of this continent are from the west and northwest in the months of December and January, and consequently blow across the Arctic current, and as the ice, according to my calculations, is making its progress over the exposed ocean between Greenland and Newfoundland at that time, — I find by careful observation, that if, say, seven weeks, beginning with December and extending into January, be very mild weather, these winds are *very light*, the ice arrives on the bosom of the Gulf Stream about the 20th of January. Again, if the weather for this observation time be medium in point of general temperature, the winds from the continent will be *stronger* and so retard the progress of the ice that it will not reach its destination before the middle of Feburary. And again, if the temperature be *very severe* during this observation time powerful and continuous winds will drift the ice far eastward, across and beyond the Arctic current, so that it cannot reach its destination until the easterly winds of March and earlier drift it down upon our shores late in March, about the 20th.

My theory then very briefly put is this, —

1st. Arctic ice arriving early, it will melt out early under the influence of the warm waters of the Gulf Stream, and a more southern latitude, the balance of winter will be well sustained, the spring will be early, and the summer dry and warm.

2d. Ice arriving in the middle of Feburary, the winter, the spring, and the summer will be average.

3d. Ice arriving late, December and January will be severe weather, February or mid-winter will be easy temperature, then a sort of second winter, with a late spring and a generally cloudy summer.

Such is my theory, which I have used in practice for a period of fifteen years with success, never making a forecast wide of the mark except for the present year, which has been so far an abnormal one.

The whole is respectfully submitted for criticism.

T. SHAW CHAPMAN.

MARBLETON, QUEBEC, July 14, 1892.

ADMIRAL SEMMES, C. S. N., IN THE VORTEX OF A CYCLONE.

Editor of the American Meteorological Journal : —

In Mr. Ballou's recent article on "The Eye of the Storm" there does not appear any reference to the description of the passage through such a vortex by Admiral R. Semmes, C. S. N. ("Memoirs of Service Afloat," Baltimore, 1869, page 473), and as his book is not, perhaps, widely circulated, a reproduction of his description will probably be of interest and value.

H. H. C.

He says: "The cyclone of which I am writing must have travelled a couple of thousand miles before it reached the 'Alabama.' Its approach had been heralded by several days of bad weather, and on the morning of the gale, which was on the 16th of October (1862), the barometer — that faithful sentinel of the seaman — began to settle rapidly. . . . The ship is lying still and the storm, which is travelling to the northeast, is approaching her. She was soon enveloped in its folds, and the winds, running around the circle in their mad career, howled, and whistled, and screeched around her like a thousand demons. . . . The waves began to assault her with sledge-hammer blows, and occasionally to leap on board of her, flooding her deck and compelling us to stand knee-deep in water. . . . The lee-quarter boat was wrenched from the davits, and dashed in pieces; and as the sea would strike the ship forward or aft she would tremble in every fibre. . . .

"The storm raged thus violently for two hours, the barometer settling all the while until it reached 28.64. It then fell suddenly calm. Landsmen have heard of an 'ominous' calm, but this calm seemed to us almost like the fiat of death. We knew at once that we were in the terrible vortex of a cyclone, from which so few mariners have ever escaped to tell the tale! . . . The scene was the most remarkable I had ever witnessed. The ship, which

had been pressed over only a moment before by the fury of the gale, as described, had now righted, and the heavy storm staysail, which, notwithstanding its diminutive size, had required two stout tackles to confine it to the deck, was now, for want of wind to keep it steady, jerking those tackles about as though it would snap them in pieces as the ship rolled to and fro! The aspect of the heavens was appalling. The clouds were writhing and twisting, like so many huge serpents engaged in combat, and hung so low, in the thin air of the vortex, as almost to touch our mast-heads. The best description I can give of the sea is that of a number of huge watery cones, — for the waves seemed now in the diminished pressure of the atmosphere in the vortex *to jut up into the sky*, and assume conical shapes, — that were dancing an infernal reel played by some necromancer. They were not running in any given direction, there being no longer any wind to drive them, but were jostling each other, like drunken men in a crowd, and threatening every moment to topple one upon the other.

"With watch in hand I noticed the passage of the vortex. It was just thirty minutes in passing. The gale had left us with the wind from the southwest; the ship the moment she emerged from the vortex took the wind from the northwest. We could see it coming upon the waters. The disorderly seas were now no longer jostling each other; the infernal reel had ended, the cones had lowered their rebellious heads as they felt the renewed pressure of the Atmosphere, and were being driven like so many obedient slaves before the raging blast. The tops of the waves were literally cut off by the force of the winds, and dashed hundreds of yards in blinding spray. The wind now struck us 'butt end foremost,' throwing the ship over in an instant, as before, and threatening to jerk the little storm sail from its bolt ropes. It was impossible to raise one's head above the rail, and difficult to breathe for a few seconds. We could do nothing but cower under the weather bulwarks, and hold on to the belaying pins, or whatever other objects presented themselves, to prevent being dashed to leeward, or swept overboard. The gale raged, now, precisely as long as it done before we entered the vortex, — two hours, — showing how accurately Nature had drawn her circle."

EFFECT OF HIGH WINDS ON THE BAROMETER, AND TEMPERATURE FORECASTS FROM SUNSET COLORS.

Editor of the American Meteorological Journal: —

In Mr. Ballou's recent article on "The Eye of the Storm" his diagram of the barographic trace during the Martinique hurricane shows two deep dips of the barometer, one immediately before and one immediately after the central calm. The dips, I feel confident, were caused by the terrific winds blowing across the apertures in the deck and sucking the air out of the vessel, thus causing the barometer to read some two tenths of an inch below its true height. It has been shown in the publications of the Blue

Hill Observatory that high winds blowing across the Observatory sometimes lower the barometer a tenth of an inch.

In Prof. Harrington's pamphlet on "Meteorological Work for Agricultural Institutions" he says: "It is important that all means of local forecasts, independent of the weather map, should be carefully studied, and when any one is found useful it should be published in such a way as to be put at the service of those interested in it." There are two conditions of the sunset colors which seem to indicate the coming temperature for the next day. I have observed the connection in Tennessee, Michigan, and Massachusetts, but do not remember to have seen it anywhere in print. They are as follows: First, when the sun sets in a smoky atmosphere as a reddish ball, and if after setting there is next the horizon a grayish or smoky color, surmounted by a dull reddish glow, it indicates high temperature for the next day. Second, when the sun sets in a streak of very clear sky near the horizon, and after setting lights up low clouds with a brilliant fiery red, like the reflection from a conflagration, it indicates cool or cooler weather for the next day.

I would be pleased to have observers make the necessary records to test these conclusions.

H. HELM CLAYTON.

BLUE HILL OBSERVATORY, READVILLE, MASS.

WINTER THUNDERSTORMS.

Editor of the American Meteorological Journal:—

Since writing the note on Winter Thunderstorms in the August number of the JOURNAL I have had occasion to consult Buchan's Report on *Atmospheric Circulation*, based on observations made in the voyage of the "Challenger," and published in 1889. On page 31 *et seq.*, he says: "Of forty-five thunderstorms recorded [during the three and a half years of the voyage], twenty-six occurred over the open sea, and nineteen near land. Of those recorded over the open sea twenty-two occurred during the ten hours from 10 P. M. to 8 A. M., whereas during the other fourteen hours of the day only four occurred. . . . Hence the important conclusion that over the open sea thunderstorms are essentially phenomena of the night, and occur chiefly during the morning minimum of pressure. On the other hand, as regards the thunderstorms which occurred near land, they are pretty evenly distributed during the twenty-four hours. . . . It has been shown that over the open sea thunderstorms are essentially nocturnal phenomena. As regards thunderstorms over the land surfaces of the globe, the disturbance of atmospheric equilibrium, resulting in ascending and descending currents, is brought about mainly by the super-heating of the surface and thence of the lowermost strata of the air. But as regards the open sea, this mode of disturbing the atmospheric equilibrium cannot take place, inasmuch as the influence of solar radiation is only to raise the temperature of the surface of the sea not more than a degree. Hence it is probable that the disturbance of the equilibrium of the atmosphere in the case of thunderstorms over the open sea

is brought about by the cooling of the higher strata of the atmosphere by terrestrial radiation."

This gives a most satisfactory confirmation to my suppositions. It is still of interest to inquire whether the marine thunderstorms occur only within areas of cyclonic clouds, or whether, when occurring at night, they ever have the isolated form common in summer afternoon thunderstorms on land.

W. M. DAVIS.

ELECTRICAL STORMS IN CALIFORNIA.

Editor American Meteorological Journal:—

Inclosed please find a query for insertion in your JOURNAL of METEOROLOGY. Would like to have some meteorologist give the true explanation of this singular fact, if possible. I cannot find anybody here who can explain it. Some have assigned reasons, but none are satisfactory to me.

Yours truly,

JNO. D. PARKER,
Post Chaplain, United States Army.

SAN DIEGO, CAL., July 12, 1892.

Can any one give the true cause for the absence of electrical storms in Southern California outside of the mountain ranges? Thunderstorms occur in the Sierra Madre, or Coast Range, and in Arizona on the eastern side of this range of mountains, but none in Southern California on the western side. A gentleman living in Los Angeles said he had heard but one clap of thunder there in the last four years. Once I saw the lightning, during the past year at San Diego, playing in a cloud far out at sea.

A MIRAGE IN WASHINGTON.

Editor American Meteorological Journal:—

On June 25, at about 4 P. M., I had my first view of a mirage, not on the sands of a desert but on the asphalt pavements of Washington. On looking over the crest of a gentle elevation in the street I saw on the farther side the appearance of a sheet of water, with people and vehicles on the street reflected therein. On passing to the opposite side of the crest and looking back, there appeared to be another sheet of water, where I had recently stood, with similar reflections. The sun was shining brightly, and of course the phenomenon was due to a heated layer of air next the pavement. On calling the attention of a bystander to the appearance, I learned that one or two similar cases had recently been mentioned in the city papers. After going several blocks I saw another mirage of similar character, but less perfect, again over the crest of a rise of ground. I infer that the mirage may not infrequently be seen over pavements or other surfaces of sufficient heat-absorbing capacity. Systematic observations of this phenomenon under different circumstances might afford some interesting deductions.

A. L. COLTON.

WASHINGTON, D. C., June 27, 1892.

BIBLIOGRAPHICAL NOTES.

CHANGES OF LEVEL IN THE OCEANS.

GUSTAV RITTER V. WEX. *Periodische Meeresanschwellungen an den Polen und am Æquator.* Pages viii., 60; plates iv. Vienna, 1891.

Von Wex, who is known everywhere as one of the most eminent hydraulic engineers, publishes in this pamphlet his development of a theory as to the causes of the mutations of oceans and continents, and of the periods of the glacial epochs of either hemisphere. This theory was arrived at quite independently of the similar theory published by Prof. Schmick in 1869, and again that of Prof. Falb, announced by him in 1889. It is not evident how much additional weight a theory should receive simply because it is adopted by three or more eminent scientists; but it seems certain that the present theory considers only three of the many causes that may have conspired to produce great changes on the earth's surface. Von Wex states that he thinks he has been successful, by means of a graphic presentation of the elements of motion, in proving that by the simultaneous combined influence of (1) the progress of the four annual seasons on the circumference of the earth's orbit from east to west, (2) the rotation of the major axis of the earth's orbit around the sun's centre from west to east, (3) the variation in the inclination of the ecliptic from its maximum to its minimum, there have naturally arisen periodical accumulations of the waters of the ocean alternately at either pole and at the equator, by reason of which there have been brought about periodical floodings of the polar and the equatorial lands, as also the floods in the Temperate zones, and the glaciation of the Alps; finally, this has brought about the complete interchange of the annual seasons and temperatures in the respective latitudes, as also the glacial epochs in the polar regions. The author finds a principal period of twenty-one thousand years from flood to flood, and of course a similar period in the insolation of the earth's surface.

Among other conclusions we note first, that the changes of level observed on the Baltic coast have been due to the accumulation of the ocean water in the north polar regions; second, by reason of the form of the surface of the sea the coast line attains its greatest height in a given region that must lie between two regions of smaller height. The lowest coast line formed by the flood of 9250 B. C. was at Throndheim about one hundred and fifty meters above the present sea level. This flood must have lasted for about two thousand years without a change of one meter, plus or minus, which gave the surf of the North Sea time enough to erode a broad beach even in the hardest rock. The author considers the Deluge of Noah to have been a natural phenomenon (and in fact an extended flood in the Lower Euphrates

and surrounding lowlands of Mesopotamia), and that it is directly attributable to an earthquake under the Persian Gulf combined with a cyclonic wind from the south, and was therefore purely a local affair.

Von Wex maintains that the first men in Europe did not live simultaneously with the diluvial mammals, that is to say, thirty-five thousand five hundred years B. C., and furthermore, that it was after the third great flood, or 14500 B. C. that the first human beings originated on the high plains of Asia.

While it is necessary that the METEOROLOGICAL JOURNAL should notice the publication of new theories by prominent men, yet it is not improper, as a word of caution, to add that the preceding matters are at present far beyond the limitations of exact knowledge. The astronomical periods here quoted may be approximately exact, but our knowledge of the elasticity and viscosity of the earth's crust forbids us to apply these periods in the simple manner adopted by von Wex. Our knowledge of meteorology is not yet sufficient to allow us to state the necessary characteristics of an existing glacial epoch, much less to predict those of former ages; neither can any such theory as the preceding look for its confirmation to the fact that it predicts the time and place of the Noachic Deluge, since we have not yet cleared up the question as to how much of the Biblical and Babylonian narratives is history and how much is myth. C. A.

NOTES ON THE CLIMATE OF DEATH VALLEY.

MARK W. HARRINGTON. *Notes on the Climate and Meteorology of Death Valley, Cal.* United States Department of Agriculture, Weather Bureau. Bulletin No. 1. 8vo, pages 50.

This interesting report deals with the meteorological results of an exploration of Death Valley made in 1891, under the direction of Dr. C. Hart Merriam, with the co-operation of the Geological Survey and the Signal Service, continued by the Weather Bureau. The valley lies between latitudes 35° 40′ and 36° 35′ north and longitudes 116° 15′ and 117° 5′ west from Greenwich. It is about seventy-five miles long, and the bottom is only twelve or fifteen miles wide at its widest point. The surrounding mountains are from two thousand to ten thousand feet high. The valley was probably formerly the bed of a lake of bitter water, as deposits of salt and borax testify. At the northern end of the valley is a salt marsh, but the few streams which flow into the valley dry up soon after they enter it. The water, which can be found during the dry season by digging a few feet at almost any point, is usually bitter and unfit for drinking.

The meteorological station was established on April 30, 1891, and the observations were continued till the end of September. The instruments were, in most respects, the standard instruments supplied to the second order stations of the Bureau, with the addition of a Richard barograph and thermograph. The maximum pressure observed was 30.30, on May 22, and the minimum 29.41, on Sept. 30. The monthly ranges are very large, and the

diurnal range is of the purest single maximum type, and has the largest amplitude known. The absolute maximum temperature recorded was 122° F., which was reached on several days, but this has been surpassed at Mammoth Tank, in the Colorado Desert, in this country, where in July, 1887, the temperature reached 128° in the shade. The lowest temperature recorded was on May 21, 54°. On July 18 the maximum temperature was 120°, the minimum 99°, and the mean of all hours 108.6°. The mean temperature of the five months was 94°.

The lowest recorded relative humidity was five per cent, the highest seventy-five per cent, the average twenty-three per cent. The nearest approach to dew was on Aug. 17, when the dew-point was 70°, and the temperature 79°. On Aug. 4 the dew-point was 22°, and the actual temperature in the shade 112°. The rainfall for the entire period of five months was 1.40 inches, the rain being always either a slight sprinkle or a thunderstorm. On Aug. 16 when half an inch of rain fell, the relative humidity of the thin lower superheated stratum of air was only eighteen per cent. The winds show evidence of a diurnal change, due to the heating and cooling of the higher valley to the north, the south winds being more than twice as frequent in the evening as in the morning, and the north winds less than half as frequent. The principal maximum wind velocity occurs towards sunset, and there is a secondary minimum about noon. This may possibly be explained by the strong ascensional currents about noon, which may change some of the horizontal to vertical motions. A comparison of the climate of Death Valley in summer with other regions of excessive heat, in the Sahara and India, shows that Death Valley is much hotter and much drier than the others.

BULLETIN OF THE ITALIAN METEOROLOGICAL SOCIETY.

Societa Meteorologica Italiana Bulletino Mensuale.

T. BERTELLI. *Memoria Storica intorno alla scoperta della declinazione.*

The "Monthly Bulletin of the Italian Meteorological Society" has reached the twelfth volume of its second series, having been begun in 1866, as the "Meteorological Bulletin of the Observatory at Moncalieri." The Italian Society, as well as its Bulletin and other publications, owe its existence to the enthusiasm and energy of Fr. Francesca Denza, who represents the voluntary and, to a certain extent, the Roman Catholic Church element in Italian meteorology.

The current number of the Monthly Bulletin is largely devoted to the shooting stars of August, 1891. Indeed, what with meteors, earthquakes, tides, and terrestial magnetism, the Bulletin covers the whole range of terrestial physics, or "geodynamics," but gives a full share of attention to meteorology.

An interesting original article is contributed by Fr. Bertelli, *i. e.*, a synopsis of his extensive historical memoir on the discovery of the declination of the magnetic needle, commonly attributed to Christopher Columbus, Sept. 12, 1492.

Perhaps few realize that four hundred years ago it was vaguely supposed that the magnetic needle pointed towards some unknown northern region where an attracting mass of iron ore lay concealed beneath the earth; men were not then generally clear in their own minds that the earth was a globe, or that it had an axis of diurnal rotation; but Christopher Columbus was one of those who did believe in these new ideas, and, by reason of his extensive voyages, he was probably the only one who was then familiar with the fact that the departure of the magnetic needle from the true meridian varied from port to port wherever he sailed. Columbus was a precise observer and an acute reasoner; he was not disturbed by those large changes in the declination of the needle that frightened his seamen on his first voyage to America, but, conscious of the importance of the subject, he was careful to record the date and place in mid-ocean at which his needle pointed to the true north, and thus gave the world that first record of the line of zero declination that has ever since been considered the starting-point of our knowledge of the distribution of terrestial magnetism and its secular variations.

The secular variation of the magnetic declination deduced from observations year after year at the same place is properly ascribed to Gilbert, but its geographical variation was first discovered by Columbus. It is this latter statement that is especially established by the exhaustive studies of Bertelli, although perhaps the same fact is broadly outlined in Walker's "Prize Essay on Terrestial Magnetism." London, 1863. C. A.

THE CIRCULATION OF THE ATMOSPHERE OF PLANETS.

MARSDEN MANSON. *The Circulation of the Atmosphere of Planets.*

In this article, published by the Technical Society of the Pacific Coast, (Vol. IX., No. 5), the author has attempted a popular exposition of the circulation of the atmosphere of the earth with applications to other planets. The problem is certainly a complex and difficult one, but Mr. Manson has proposed merely to develop one feature viz., "the prime mode of action of solar energy in producing atmospheric circulation." He begins with a diagram illustrating the diurnal variation of the barometer, and its relations to local time, sunshine or cloudiness and solar heat, and finds that a region of maximum barometer exists on the west side of the noon meridian and a region of diurnal minimum exists on the east side. These are about six hours apart; and he assumes that a steady flow of air, namely, a westerly wind, must continually move from the high pressure to the low pressure. There is, however, an apparent stoppage of the wind in the calms of Cancer and Capricorn, and also at the Doldrums; and there is an inversion of the west winds within the region of easterly trades. The explanation of these observed facts leads the author to consider the tangential velocity for each latitude, and also the effect of the accumulation of clouds at the Doldrums. The argument in this part of the paper seems to us quite obscure and unsatisfactory. The problem of the general circulation of the atmosphere, after having been

greatly advanced by Ferrel's researchers, has of late years been relegated to the most skilful students of hydrodynamics. Helmholtz, Oberbeck, Guldberg, Mohr, Sprung, and Müller have each contributed so much to advance our knowledge that one owes it to himself to study these works before publishing a new theory of atmospheric circulation. C. A.

PUBLICATIONS RECEIVED.

"Meteorologische Zeitschrift," Wien., Heft 6, June, 1892. The principal articles are: "Ueber die Hauptresultate der Untersuchungen von Prof. Wolf in Zürich im Gebiete der Sonnenphysik," by A. Wolfer; "Die Ursache atmosphärischer Strömungen," by Prof. M. Möller; "Ueber die nöthige Zahl von Stationen für Cirrus-Beobachtungen," by Dr. Hildebrandsson.

"Das Wetter," Braunschweig, 9 Jahrgang, Heft 6, June, 1892. The articles in this number include the following: "Ueber typische Vertheilung der Temperatur in Mitteleuropa," Dr. G. Schwalbe; "Wird die Influenza durch den Wind verbreitet?" Dr. C. Lang; "Wolken und Wolkenphotographie," C. Kassner.

"Ciel et Terre," Brussels, No. 8, June 16, 1892. This contains abstracts of Dr. Van Bebber's recent article on the Extreme, Mean, and Absolute Temperatures of Europe, of Mr. Aitken's address on the Dust of the Atmosphere and its Relation to Meteorological Phenomena, and a monthly climatological review for May.

"The American Journal of Science," New Haven, Conn., Third Series, Vol. XLIV., No. 259, July, 1892.

"Pilot Chart of the North Atlantic Ocean." Published monthly by the Hydrographic Office, Bureau of Navigation, Navy Department, Washington, D. C., Richardson Clover, Lieutenant Commander, U. S. N., Hydrographer, July, 1892. This issue has a chart of the Sable Island hurricane of Aug. 29, 1891, accompanied by a number of reports from vessels in connection with the storm. This hurricane was one of small diameter but great intensity, and furnishes a typical example of this class of storms. A supplementary chart on North Atlantic ice gives a complete list of May and June ice reports received up to the date of publication.

"Tennessee Journal of Meteorology, devoted to the Interests of the Tennessee Weather and Crop Service," Nashville, J. B. Marbury, editor and publisher, Vol. I., No. 7, June, 1892. Twelve pages.

"Weekly Weather Crop Bulletin of the North Carolina Weather Service, in Co-operation with the United States Department of Agriculture, Weather Bureau," Raleigh, H. B. Battle, director.

"Weather Crop Bulletin of the Washington Weather Service, in Co-operation with the United States Department of Agriculture, Weather Bureau," Olympia, E. R. Olney, Weather Bureau, director.